Water Resources Inventory and Assessment:

Patuxent Research Refuge
Laurel, Maryland

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Contents

1. EXECUTIVE SUMMARY

Water Resources Inventory and Assessments (WRIA) are being developed by a national team of hydrologists within the U.S. Fish and Wildlife Service (Service). The purpose of these assessments is to provide reconnaissance level information on water resources at National Wildlife Refuges and National Fish Hatcheries. The goal of every WRIA is to provide a basic understanding of the water resources that are important to the facility and assess the potential threats to those resources. Data collected in the WRIAs is being incorporated into a national database so water resources can be evaluated nationally and between regions. Information collected for the WRIAs can be used to support CCPs, Hydro-Geomorphic Assessments, and other habitat management plans.

1.1 FINDINGS

1. Average total precipitation for the year in the vicinity of Patuxent Research Refuge is 43 inches. Precipitation is distributed evenly throughout the year, averaging about 3.6 inches/month.

2. Approximately 20% of the acquisition boundary area is considered wetlands using the National Wetland Inventory classification system. 85% of the wetland area is classified as forested wetlands.

3. There are 14 water supply wells on the refuge. These wells are used to water captive animals and for domestic purposes. Water use from these wells is regulated under four permits issued by the Maryland Department of Environment.

4. The Patuxent, Little Patuxent, and Midway Branch rivers are considered water quality limited and are listed on the state's 303(d) list of impaired waters.

5. 108 water quality monitoring sites were identified on or near the refuge. Not all sites are actively monitored. Water quality monitoring is carried out by a variety of state, local, federal, and non-governmental organizations.

6. Water quantity monitoring near the refuge is largely carried out by U.S. Geological Survey (USGS). Eight surface water and groundwater monitoring stations are operated in the vicinity of the refuge by USGS.

7. Long term climate records show evidence of multi-year dry and wet periods. 1955-1970 was a particularly dry period while the 1990s were particularly wet.

8. Long term climate records indicate air temperature near Patuxent Research Refuge has increased approximately 3 degrees Fahrenheit (^{o}F) since 1940.

9. Long term climate records indicate annual precipitation totals have increased about 0.11 inches/year since 1940.

10. There is an extensive network of roads on the refuge. Only 35% of the land in the acquisition boundary might be considered “roadless.” Meaning it is more than 0.1 mile from a refuge road and 0.25 miles from a major highway or interstate.

11. Studies of the Little Patuxent and Patuxent River indicate the extensive urbanization in their watersheds is the primary cause of impaired water quality in those rivers.

12. Biological inventories of refuge streams indicate most have low aquatic species diversity and suffer from impaired water quality.

1.2 RECOMMENDATIONS / FURTHER ACTIONS

The primary threat to water resources at Patuxent Research Refuge is poor water quality. Most water quality concerns are associated with pollution from extensive urban development in the watersheds surrounding the refuge. Additionally, refuge roads and historic land use may further compromise water quality.

1. Mary Kazansteva’s work highlights the numerous water quality monitoring efforts that have taken place on, and near, Patuxent Research Refuge. Mary determined that the different efforts remain somewhat uncoordinated, making it difficult to draw conclusions about refuge water quality conditions from the various datasets. Recommend putting more time into trying to summarize the results of the various monitoring efforts and identify gaps in the data collection efforts. A more thorough review will help identify how to focus future water quality monitoring to better address refuge concerns.

2. Studies and monitoring data indicate water resources on Patuxent Research Refuge suffer from compromised water quality conditions. This preliminary review suggests causes are related to stormwater runoff from neighboring properties, impacts from refuge roads, and past land use. Recommend implementing a more thorough inventory of water quality conditions in refuge streams and wetlands. This inventory could follow the format outlined in the Victoria and Markusic (2009) report or the Maryland Biological Stream Survey. Such an inventory could help pinpoint impaired waters across the refuge and identify the causes of impairment. Additionally it could identify high quality waters at Patuxent Research Refuge.

2. INTRODUCTION

This Water Resource Inventory and Assessment (WRIA) Summary Report for Patuxent Research Refuge (NWR) describes current hydrologic information, provides an assessment of water resource issues of concerns, identifies water resource needs, and makes recommendations regarding refuge water resources. The information contained within this report and supporting documents will be entered into the national WRIA database.

Together, the national WRIA database and summary reports are designed to provide a reconnaissance level inventory and assessment of water resources on National Wildlife Refuges and National Fish Hatcheries. A national team of U.S. Fish and Wildlife Service (Service) Water Resource staff, Environmental Contaminants Biologists, and other Service employees developed the standardized content of the national WRIA database and summary reports.

The long term goal of the National Wildlife Refuge System (NWRS) WRIA effort is to provide up-to-date data on a facility's water quantity and quality in order to protect adequate supplies of clean and fresh water. An accurate water resources inventory is essential to prioritize issues and tasks, and to take prescriptive actions that are consistent with the established purposes of the refuge. Reconnaissance-level water resource assessments evaluate water rights, water quantity, known water quality issues, water management, potential water acquisitions, threats to water supplies, and other water resource issues for each field station.

WRIAs are recognized as an important part of the NWRS Inventory and Monitoring (I&M) Program and are outlined in the I&M Draft Operational Blueprint as Task 2a. Hydrologic and water resource information compiled during the WRIA process will help facilitate the development of other key documents for each refuge including Hydrogeomorphic Analyses (HGM) and Comprehensive Conservation Plans (CCP).

Patuxent Research Refuge WRIA

This WRIA Summary Report for Patuxent Research Refuge incorporates hydrologic information compiled between August 2010 and November 2010. The report is intended to be a reference for ongoing water resource management and strategy development. However, the document is not meant to be exhaustive or a historical summary of activities at Patuxent Research Refuge.

3. FACILITY INFORMATION

Patuxent Research Refuge

Patuxent Research Refuge was established in 1936 by Executive Order of President Franklin D. Roosevelt for the purpose of supporting wildlife research. Some of the original research in wetland habitat management and environmental toxicology was carried out by Service scientists at Patuxent. Additionally, the refuge was the first location in the nation to raise endangered Whooping Cranes. Today most of the research on the refuge is conducted by the U.S. Geological Survey (USGS) through the Patuxent Wildlife Research Center.

The refuge protects nearly 12,841 acres of land surrounding the Patuxent and Little Patuxent Rivers between Washington, D.C. and Baltimore, MD (Figure 1). The majority of refuge lands were formerly managed by the Departments of Agriculture and Defense. Most of the refuge is mixed deciduous forest with both man-made and natural wetland habitat. The refuge is surrounded by dense suburban development and is one of the largest tracts of protected land on the Washington D.C. / Baltimore, MD corridor.

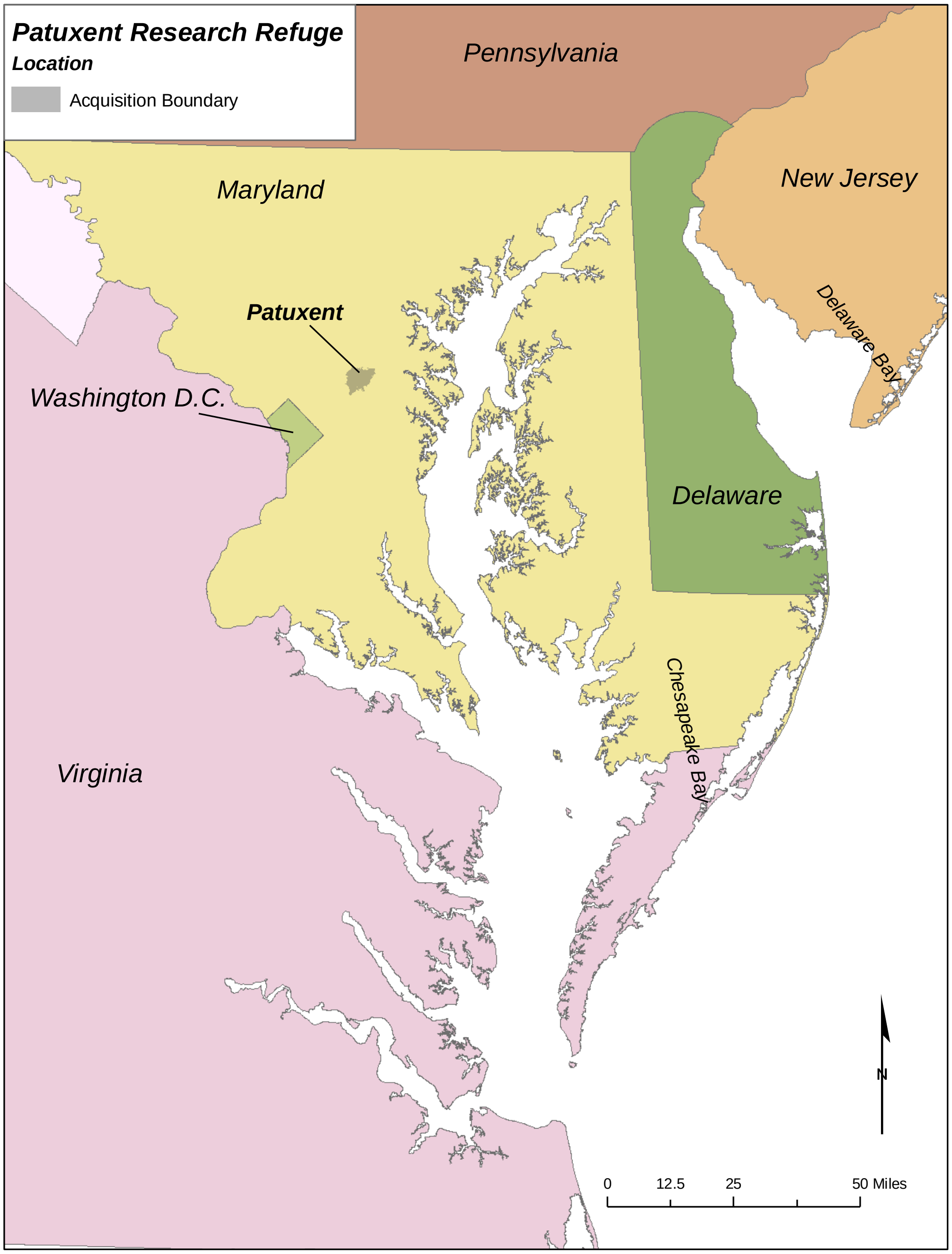

Figure 1: Location of Patuxent Research Refuge in Laurel, MD.

4. WATER RESOURCES

4.1 Rivers / Streams / Creeks

The WRIA relies on U.S. Geological Survey 1:24,000 scale National Hydrography Dataset (NHD) to inventory streams at Patuxent Research Refuge (Table 1, Figure 2). The focus of the preliminary analysis is on named NHD features because they tend to be the largest and, theoretically, of most interest to Service facilities.

Table 1: Named creeks and streams from the USGS 1:24,000 National Hydrography Dataset. Includes features on or within 0.1 miles of Patuxent's approved boundary.

Stream Name	Miles on Refuge
Patuxent River	7.6
Little Patuxent River	5.3
Midway Branch / Rogue Harbor	2.7
Thomas Branch	1.9
Total	***17.4***

The Patuxent and Little Patuxent rivers pass through the refuge and originate many miles upstream of the refuge boundary. The watersheds of the two rivers are characterized by rolling hills and gently sloping terrain with broad valleys and small tributary streams. The distribution of land use in the Little Patuxent watershed is characteristic of both watersheds with approximately 52% suburban, 36% forest, 9% agriculture, and 3% pasture (MDE 2009).

The Patuxent and Little Patuxent rivers are classified as Use I (water contact recreation and aquatic life) and Use I-P (water contact recreation, aquatic life, and public water supply), respectively, by the Maryland Department of Environment (MDE). These classifications are required under section 303(d) of the Clean Water Act and used to determine if the rivers are water quality impaired. The Patuxent River is considered one of the State's Scenic Rivers, which is a designation designed to preserve the natural values of the river.

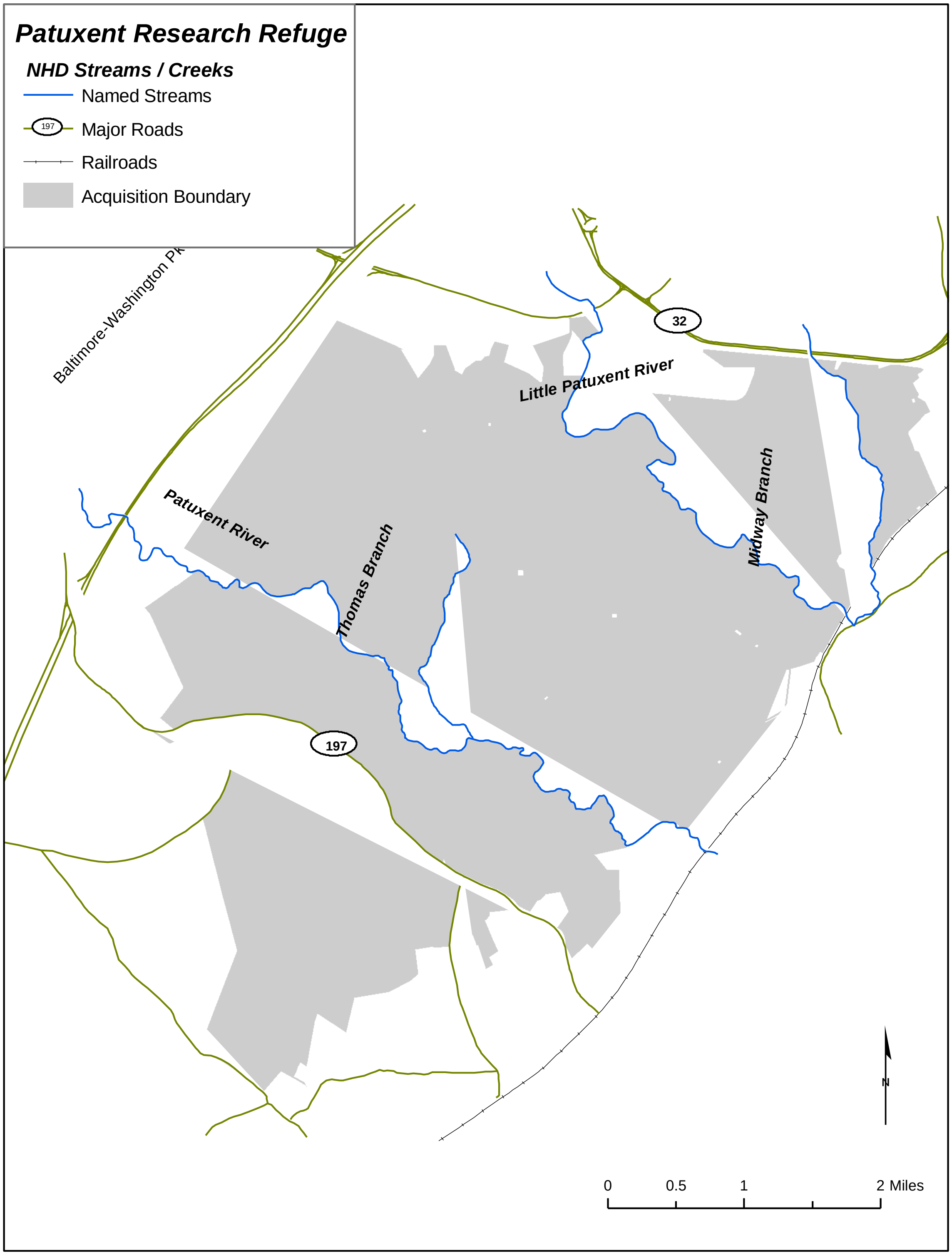

Figure 2: Named creeks or streams from the USGS National Hydrography Dataset within the Patuxent Research Refuge approved boundary, Laurel, MD.

4.2 Lakes, Ponds, and Impoundments

Nearly all surface water features at Patuxent are man-made impoundments with the exception of the Shangri-la and Beaver Valley oxbows near the Little Patuxent River (Figure 3). Most impoundments were constructed at the refuge between 1938 and 1974 to support studies of freshwater wetland and waterfowl management (Obrecht 1988). More recently, impoundments have been constructed to minimize stormwater runoff from neighboring suburban development or for sewage treatment at refuge facilities. Some ponds were created inadvertently when roads were constructed across seasonal drainages. Total acreage of the refuge's ponds and lakes is about 570 acres, or 4.4% of the land in the refuge's acquisition boundary (Table 2 and Figure 3).

Table 2: Acreage of impoundments in the Patuxent Research Refuge, Laurel, MD.

POND	ACRES	POND	ACRES	POND	ACRES
Millrace	58	Greentree Reservoir	6.4	Salamander	1.6
Cash Lake	54	Hance 2	6.2	Fire Control Pond	1.6
Knowles 1	43	Wood Duck Pond	5.9	Sundew Pond	1.6
Lake Redington	35	Shaefer Farm Pond	5.8	Bluegill	1.4
Beaver Valley	30	WSSC	5.8	Old Gravel Pit Pond	1.4
Shaefer Lake	24	Uhler 2	5.5	Goose Pond	1.2
Lake Allen	20	Bullfrog	5.0	Peeper Pond	1.0
Knowles 2	19	Telegraph Swamp	4.7	Farm Pond	0.88
Shangri-La	19	Kingfisher	4.5	Gravel Pit Pond	0.86
Knowles 3	16	Telegraph Swamp	4.2	Clay Pit Pond	0.76
Duvall 1	15	Mabbott Pond	4.1	Bailey Bridge Ma	0.73
K-Swamp	15	Mallard Pond	4.0	Borrow Pit 2	0.72
Patuxent Marsh	14	Range Pond	3.7	Shaefer Farm Pond	0.72
Wood Duck Pond	13	New Swamp	3.7	Mitigation Pond	0.65
Powerline Swamp	13	New Marsh	3.3	Spillway	0.53
Hobbs Pond	11	Midway Branch	2.9	Rieve's Pond	0.51
Shaefer Farm Pond	9.8	Merganser Pond	2.7	Dragonfly Pond	0.50
Blue Heron	9.2	Cattail Pond	2.7	Borrow Pit 3	0.49
Snowden Pond	8.2	WSSC	2.3	Borrow Pit 1	0.47
Rogue Harbor	8.2	Shaefer Farm Pond	2.2	End. Species Reservoir	0.40
Duvall 2	7.7	Midway	2.1	Treatment Lagoon	0.32
Hance 1	7.5	Shaefer Farm Pond	1.9	Shaefer Farm Pond	0.31
New Marsh	7.1	Treatment Ponds	1.8	Shaefer Farm Pond	0.29
Uhler 1	6.5	Harding Spring Pond	1.7	Fire Trail Pond	0.17

NOTE: Discrepancies between acreage in Table 2 and other documents are most likely due to different mapping techniques. Data in Table 2 were calculated using ArcGis software from a shapefile provided by Patuxent Research Refuge Staff.

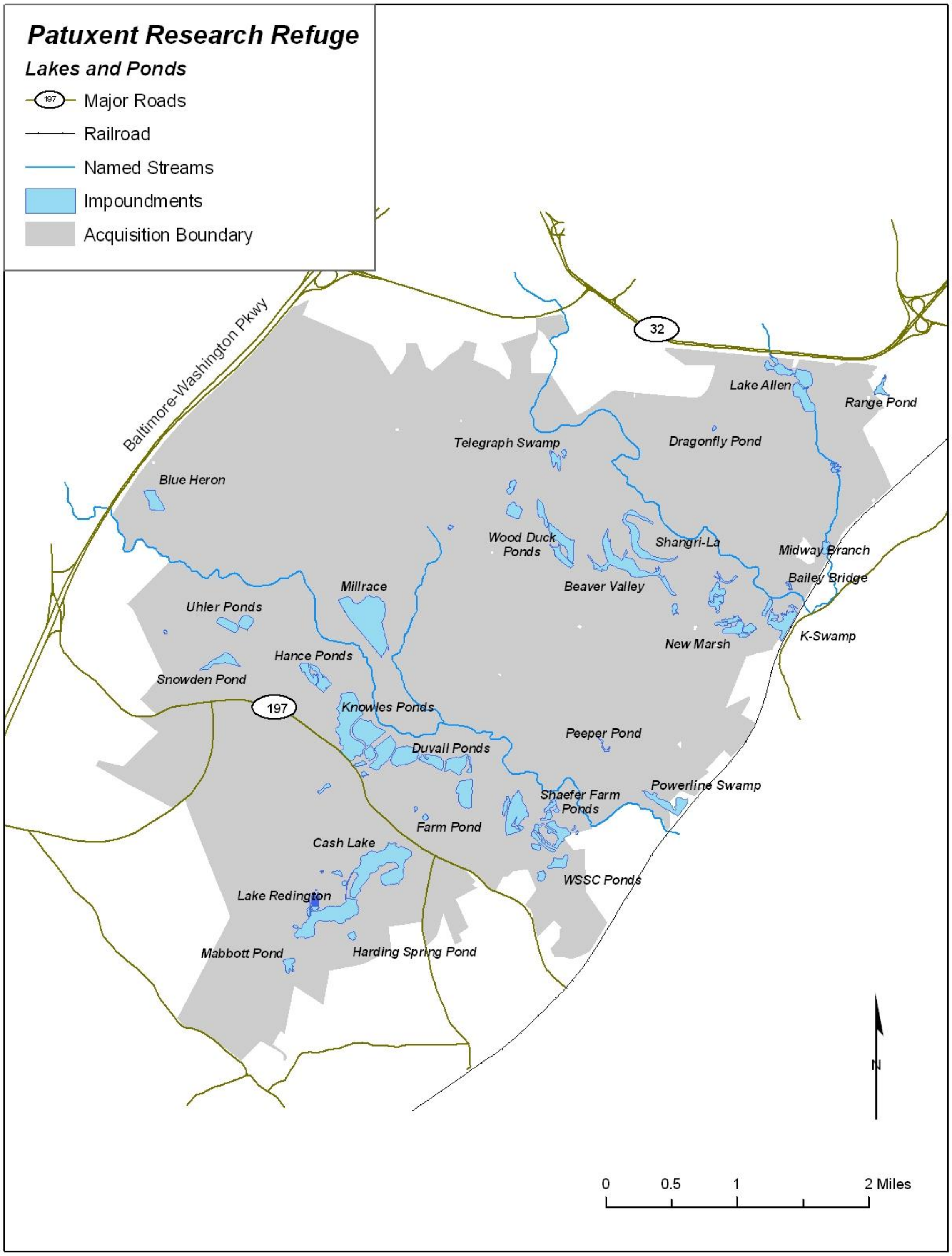

Figure 3: Impoundments of Patuxent Research Refuge, near Laurel, MD. Not all of the features are labeled in the map.

4.3 National Wetland Inventory Wetlands

The National Wetland Inventory (NWI) is a branch of the U.S. Fish and Wildlife Service established in 1974 to provide information on the extent of the nation's wetlands (Tiner 1984). The NWI produces maps of wetland habitat as well as reports on the status and trends of the nation's wetlands. Using the *Classification of Wetlands and Deepwater Habitats of the United States* (Cowardin et al. 1979) wetlands have been inventoried and classified for approximately 90% of the conterminous United States and approximately 34% of Alaska. Cowardin's classification places all wetlands and deepwater habitats into 5 "systems": marine, estuarine, riverine, lacustrine, and palustrine. Most of the wetlands in the United States are either estuarine or palustrine (Tiner 1984). The two predominant wetland classes at Patuxent NWR are defined in Cowardin et al. (1979) as:

> **Lacustrine:** the Lacustrine System includes wetlands and deepwater habitats with all of the following characteristics: 1) situated in a topographic depression or a dammed river channel; 2) lacking trees, shrubs, persistent emergents, emergent mosses or lichens with greater than 30% areal coverage; and 3) total area exceeds 8 ha (20 acres). . . . Lacustrine waters may be tidal or nontidal, but ocean-derived salinity is always less than $0.5^{o}/_{oo}$.
>
> **Palustrine**: the Palustrine System includes all nontidal wetlands dominated by trees, shrubs, persistent emergents, emergent mosses or lichens, and all such wetlands that occur in tidal areas where salinity due to ocean derived salts is below $0.5^{o}/_{oo}$ (e.g., inland marshes, bogs, fens, and swamps)

The different systems can be broken down into subsystems, classes and hydrologic regimes based on the wetland's position in the landscape, dominant vegetation type, and hydrology.

Approximately, 20% (2,570 acres) of the refuge is considered wetland using NWI's classification. Bottomland hardwood forest (Palustrine Forested) near the Patuxent and Little Patuxent river is the most extensive wetland type (Figure 4, Table 3).

Table 3: Wetland habitat delineated by the National Wetland Inventory inside the Patuxent Research Refuge acquisition boundary.

NWI	Alias	Acres	Percent of Total
Lacustrine	Lake, permanently flooded	73	0.6
Lacustrine Emergent	Emergent marsh, lake fringe	32	0.2
Palustrine Aquatic Bed	Submerged Aquatic vegetation	74	0.6
Palustrine Emergent	Freshwater emergent marsh	51	0.4
Palustrine Forested	Forested Wetland	2176	17
Palustrine Shrub	Shrub-dominated wetland	78	0.6
Palustrine Flooded	Ponds / Impoundments	42	0.3
Riverine	River bed	9	0.1
Upland		10306	80
Total		***12841***	***100***

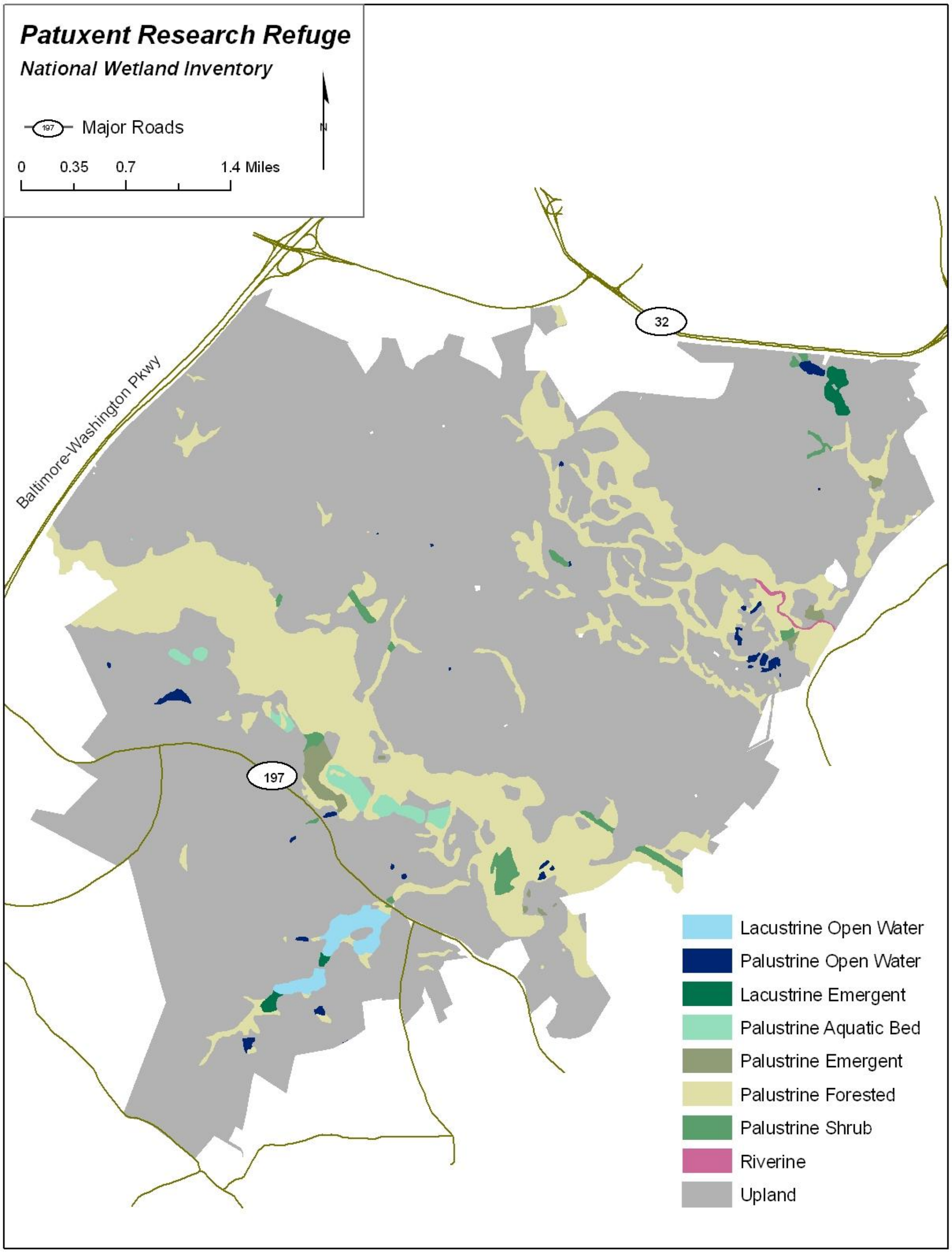

Figure 4: National Wetland Inventory wetlands at Patuxent Research Refuge NWR, MD.

5. GROUNDWATER RESOURCES

Patuxent overlies the Northern Atlantic Coastal Plain Aquifer System. The aquifer is described generally in the USGS ground water atlas of the United States (Trapp and Horn 1997). The Maryland Geological Survey provides more detailed local information on the state's groundwater aquifers. The Coastal Plain Aquifer System is comprised of unconsolidated gravel, sand, and silt separated by layers of less permeable layers, or confining beds. The more permeable sand and gravel deposits are considered aquifers and are used for public water supply (Andreasen 2007). In Anne Arundel County the aquifers names, from shallowest to deepest are: Water-table aquifer, Aquia, Magothy, Patapsco, and Patuxent (Figure 5). At Patuxent the Water-table aquifer includes shallow groundwater adjacent to rivers and wetlands within 30 ft of the ground surface. Water in this aquifer contributes to the water supply of rivers and wetlands on the refuge. Refuge water supply wells tap the Patapsco and Patuxent aquifers, which are about 280 and 500 ft below ground surface, respectively.

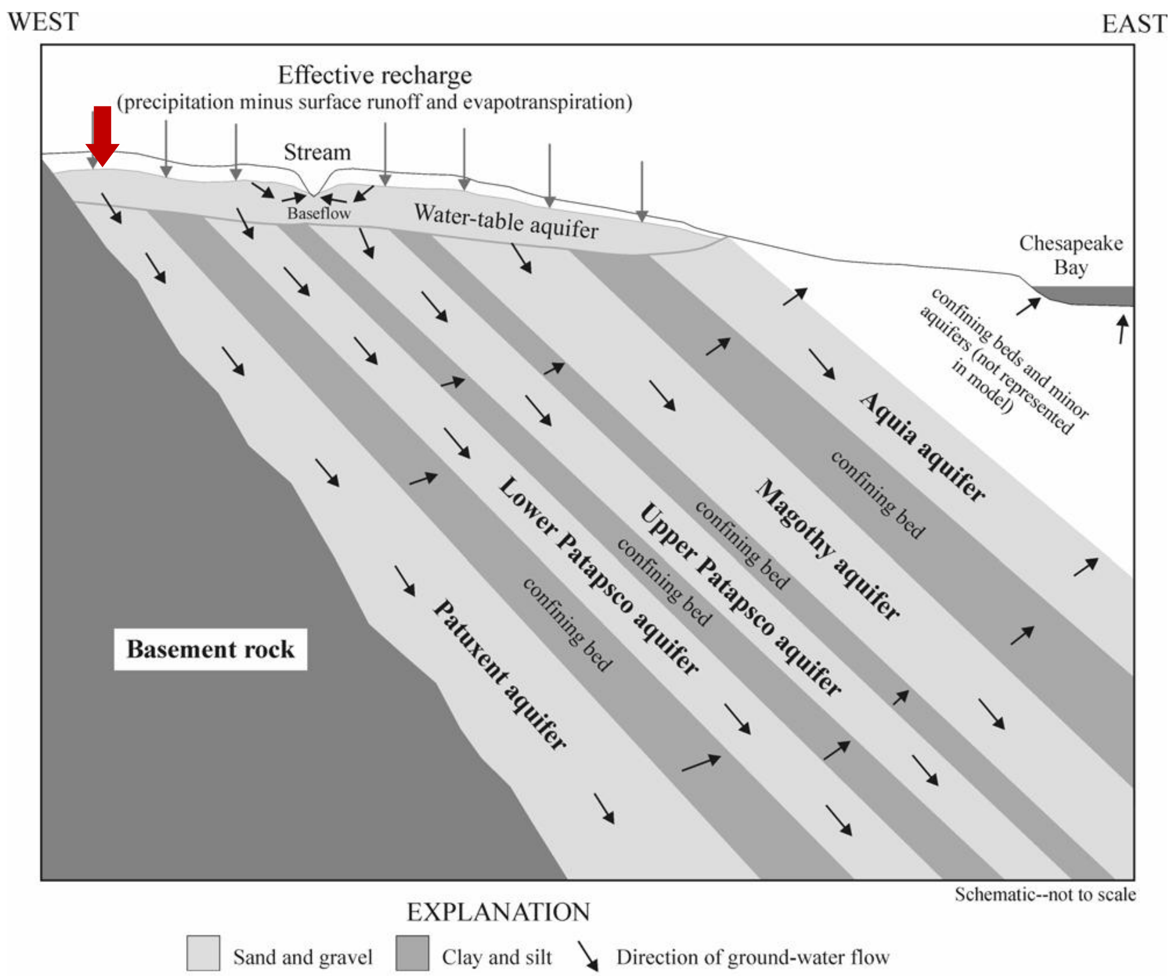

Figure 5: Conceptual model of groundwater flow in the coastal plain aquifer system in Anne Arundel County. Figure is from Andreasen (2007). Red arrow identifies approximate location of Patuxent Research Refuge.

6. WATER RELATED INFRASTRUCTURE

6.1 Impoundments

Nearly all the standing water features on the refuge are man-made impoundments (see section 4.2). Although some were created inadvertently when roads were constructed across drainages, many were constructed between the 1930s and 1970s to support wetland management research. A comprehensive review of the refuge's impoundments was completed in 1988, which culminated in an Impoundment Management Plan (Obrecht 1988).

6.2 Water Control Structures

About half of the impoundments on Patuxent have at least one water control structure on them. Most of the structures at Patuxent are the stop-log/riser variety. These structures often consist of a 24-inch, or greater, corrugated metal pipe with a riser section. Inside the riser, 2 x 4s or 2 x 6s are inserted to stop water flow and control water levels in the impoundments. These types of control structures are ubiquitous on National Wildlife Refuges around the country. Other, more elaborate control structures exist on the largest impoundments, such as Cash Lake and Lake Redington.

The Service Asset and Maintenance Management System (SAMMS) database can be a useful tool for identifying some of the water control structures at a refuge. The database can be a source of basic information on the largest and, theoretically, most significant water control structures at a refuge (Table 4).

Table 4: SAMMS output for water control structures on the Patuxent Research Refuge.

RPI No.	Description
10021669	Spillway below Cash Lake and Route 197
10021776	Lake Allen Spillway
10021781	Lake Redington Spillway
10021783	72-Inch Water Control Structure at Lake Redington
10021789	Uhler 1 Water Control Structure
10021792	Uhler 2 Water Control Structure
10021797	Bluegill Pond Water Control Structure
10021800	Cash Lake Water Control Structure

6.3 Inventory Dams

The Office of Dam Safety maintains a database of "inventory dams" on Service properties. Inventory Dams meet the following criteria:

1. The dam has a storage capacity at maximum water storage elevation in excess of 15 acre-feet, and:

    a. The dam exceeds 25 feet in height from the natural bed of the stream (or a watercourse) to the maximum water storage elevation measured at the downstream toe of the dam, or

    b. The dam is not across a stream channel or watercourse, it exceeds 25 feet in height measured from the lowest elevation of the outside limit of the dam, to the maximum water storage elevation; or

2. The dam exceeds an impounding capacity at maximum water storage elevation of 50 acre-feet and a height in excess of 6 feet; or

3. The dam has a high or significant hazard classification.

Table 5: Inventory Dams in the DAMS database for Patuxent Research Refuge. The volume of water stored in each reservoir is reported in acre-feet (ac-ft). One acre foot is equivalent to 325,851 gallons.

			Normal Pool	
Dam	**Hazard Class**	**Height (ft)**	**Volume Stored (ac-ft)**	**Surface Area (acres)**
Cash	High	16	163	49
Redington	Low	13	139	44
Snowden	Low	21	48	7
Allen	Low	11	43	20

Inventory dams are subject to periodic inspections by licensed engineers (SEED Inspections). Dams are classified as high hazard if it is likely human lives will be lost if the dam fails. In addition to formal SEED inspections high hazard dams must have an Emergency Action Plan (EAP) which identifies roles and responsibilities should a dam failure occur.

Cash Lake is considered a high hazard dam because failure could threaten drivers on US Highway 197. Refuge staff monitor water levels in the lake and at piezometers in the lake's dam.

6.4 Water Supply Wells

Water supply wells are used to pump water for captive animals used for research and for domestic purposes. The list of wells at Patuxent Research Refuge is in Table 6 below.

Table 6: Water supply wells at Patuxent Research Refuge. Information provided by Martin Brockman. Records shaded in gray are wells that have been abandoned and are no longer in use (5 total).

Well No.	Property No.	MDE Water Use Permit No.	County Well Permit No.	Location	Drill Date	Casing Size	Drill Depth
1	85	pg1958G103(03)	PG-03-1935	Quarantine Build	9/4/1958	6"	279'
1	100	pg1958G103(03)	PG-94-1251	Quarantine Build	12/16/1999	6"	278
2	85	pg1958G103(03)	PG-99-9999	Headquarters area.	3/12/1940	12"	302'
3	81	PG1958G203(02)	PG-01-0923	Log Cabin	11/6/1952	4"	145'
4	605	PG1958G203(02)	PG-99-9997	Quarters 80	12/1/1952	4"	153"
5	152	pg1958G103(03)	PG-05-2827	Cob Lab	8/15/1963	6"	290'
6	105	pg1958G103(03)	PG-67-0004	Wood line east of ES	11/7/1966	12"	433'
6	105		PG-94-1427	Wood line east of ES	6/6/2000	4"	416'
7	106	pg1958G003(05)	PG-67-0003	ES Deep well	12/2/1966	14"	606'
8	610		PG660078	South Tr	2/8/1966	4"	139'
9	171	PG1958G203(02)	PG999998	South Tr	11/29/1950	4"	115'
10	527	PG1958G203(02)	PG730248	Qt 147	8/5/1974	4"	222'
11	93	No Permit Info	No Permit Info	Qt 64	unknown	n/a	n/a
12	180	PG1958G203(02)	PG-97-0986 or PG-73-0985	Qt 64/65	5/31/1905	4"	335'
13	179	pg1958G103(03)	PG-73-0986	Coburn.	5/31/1905	6"	365'
14	14	pg1958G003(05)	PG882407	Silver Series	Not Known	8"	500'
15	A		no tag	Hunt Control	Not Known	4"	150'
16	B	AA1992G011(02)	AA-88-7584	Visitor Contact Station	3/8/1992	4"	210'
17	C	AA00G006(01)	AA-94-4537	Ed Building	Not Known		

7. WATER QUALITY

Water quality information included in the WRIA is derived from existing databases maintained by the U.S. Environmental Protection Agency (EPA). Data is publically available at the EPA's "Envirofacts" website. The website was used to collect information on listed waters and National Pollutant Discharge Elimination System (NPDES) permits in and around Patuxent Research Refuge (Figure 6, Table 7, Table 8).

Section 303(d) of the Clean Water Act requires that each state identify water bodies where water quality standards are not met. Maryland Department of the Environment (MDE) develops a list of known water quality limited rivers and lakes. Once a water body is listed, MDE needs to establish a Total Maximum Daily Load (TMDL) for the limiting substances or show that the water quality standards are being met (MDE 2009).

MDE issues NPDES permits for any discharges to waters of the United States. These permits regulate the quality and quantity of discharges into the receiving waters. Permits are issued to a variety of organizations and businesses, including the National Wildlife Refuge Visitor Center (Table 8). Stormwater and treated wastewater are two examples of discharges regulated under the NPDES program in Maryland. It is expected that wastewater discharged under these permits finds its way to the Patuxent and Little Patuxent rivers.

Table 7: Listed waterbodies at the Patuxent Research Refuge. From EPA database of listed waters.

List ID	Waterbody Name	Latest Listing	Impairment			
MD-02131105-R	Little Patuxent River	2006	Impaired Biota	Cadmium	Nutrients	Sediment
MD-02131104-T	Patuxent River	2004	Impaired Biota		Nutrients	Sediment
MD-021311050949	Midway Branch	2004	Impaired Biota			
MD-021311050949	Midway Branch (Lake Allen)	2004	Impaired Biota			

The largest rivers passing through the Patuxent Research Refuge are identified as impaired waterbodies in Maryland's 303(d) list (Table 7). It's important to note the date associated with the listing criteria in Table 7. More recent studies by MDE have found that the Little Patuxent and Patuxent Rivers are not impaired by nutrients or cadmium (MDE 2009, MDE 2007). These studies recommend removing the nutrients impairment for these rivers from the 303(d) list. Unfortunately, the national EPA database that is accessed for the WRIA does not reflect this change.

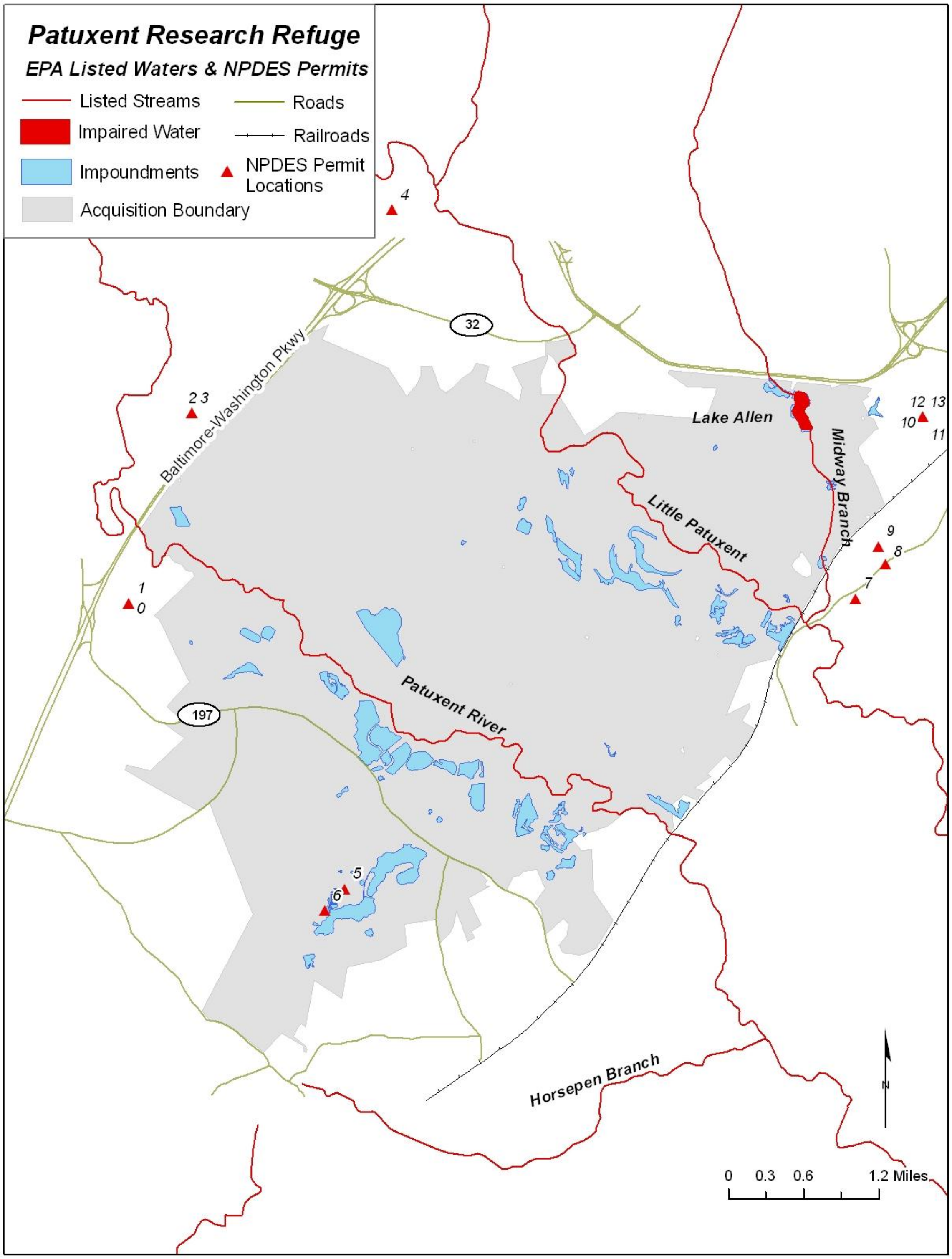

Figure 6: EPA listed waters and selected NPDES permits in and around the Patuxent Research Refuge.

NPDES permits near Patuxent Research Refuge can be identified using the EPA's Permit Compliance System database. There are numerous NPDES permits in the vicinity of Patuxent Research Refuge. The permits closest to the refuge boundary are presented in Figure 6 and listed in Table 8.

Table 8: Selected NPDES permits near Patuxent Research Refuge.

NPDES ID	Figure 6 Map ID	NAME	EPA Facility Code
MDL021725	0	Washington Suburban Sanitary Commission	110000915635
MD0021725	1	Washington Suburban Sanitary Commission	110000915635
MDL062596	2	Anne Arundel Dept. of Public Works	110000736927
MD0062596	3	Anne Arundel Dept. of Public Works	110000736927
MDG766901	4	The Meadows at Russett	110019903470
MD0065358	5	National Wildlife Refuge Visitor Center	110011128635
MD0025623	6	Patuxent Wildlife Research Center	110024526459
MDG766270	7	Riverscape Apartments	110012751129
MDG915027	8	BP Gas Station	110017855114
MDG766958	9	Cedar Ridge Community Association	110022841932
MDG912634	10	Dept. of Army: Fort Meade	110002069813
MD0021717	11	Dept. of Army: Fort Meade	110002069813
MDG912634	12	Dept. of Army: Fort Meade	110002069813
MD0021717	13	Dept. of Army: Fort Meade	110002069813

The numerous NPDES permits reflect the extent of urbanization around the Patuxent Research Refuge. The refuge lies between the population centers of Washington DC and Baltimore, MD and is in one of the most densely populated regions of Maryland. The percentage of urban land use in the Patuxent and Little Patuxent River watersheds is 40% and 53%, respectively (MDE 2006 and 2011). Impervious surfaces (parking lots, roads, housing developments, etc.) associated with urban development have major impacts on water movement across the landscape. In general, more water runs off the land more quickly in urban areas than in less developed areas. Changing runoff patterns in urban watersheds can lead to more erosion and sedimentation in stream channels. Additionally, stormwater runoff in urban areas often transmits pollutants into stream channels. In the Little Patuxent River watershed, aquatic habitat is compromised because stream channels have either been physically altered by construction or de-stabilized by altered flow regimes. Additionally, road salt residue is believed to be accumulating in the Little Patuxent River watershed, further compromising aquatic habitat (MDE 2011).

The Patuxent Research Refuge is an island of mostly forested land surrounded by suburban development. Despite the protection afforded by the refuge, studies have shown that aquatic resources on the refuge are not thriving. A 2009 evaluation of benthic invertebrates and stream habitat on the North Tract found that biological conditions in refuge streams were mostly "poor" or "very poor" (Victoria and Markusic 2009). Although the authors did not identify the causes of impairment evidence of stream channel instability and low pH values implicate altered flow regimes and historic land use. Other studies have shown that the refuge boundary does not guarantee protection from stormwater runoff from surrounding urban areas. In the late 1980s sediment runoff from an adjacent landfill reached tributary channels and wetlands on the refuge (Pinkney 2000).

7.1 Fort George G. Meade Superfund Site

Fort George G. Meade (FGGM) is located northeast of the refuge near Odenton, MD and was designated a Superfund site in 1998. Several sites on the Fort have been added to the National Priorities List (NPL) of serious abandoned hazardous waste sites. Groundwater in the Water-table aquifer under the Fort is contaminated with Carbon Tetrachloride (CCl_4), Tetrachloroethene (PCE), and Trichloroethene (TCE). FGGM has installed a network of 41 groundwater monitoring wells in the North Tract of the refuge to determine the rate of groundwater movement and extent of contaminated groundwater under the refuge (see Figure 8 for locations). At present there are contaminants in the Patapasco aquifer under the refuge but they have not discharged into refuge surface waters. If these contaminants reach the surface, the most likely discharge point to refuge surface waters is near the confluence of the Little Patuxent River and Midway Branch in the North Tract.

8. WATER MONITORING

WRIAs identify water-related monitoring that is taking place on, or near, wildlife refuges and fish hatcheries. For this preliminary review, the WRIA collects information stored in the USGS National Water Information System (NWIS) database and other readily available data sources. Water monitoring can be broadly categorized as either water quality or water quantity focused. Water quality monitoring typically consists of collecting surface water or groundwater samples for chemical analyses in a laboratory or with sensors deployed in the field. Alternative protocols may use aquatic invertebrate species as a proxy for water quality. Water quantity monitoring typically includes the flow rate in a stream or the water level in a groundwater aquifer. WRIAs also consider weather stations and tide gages as other types of water-related monitoring.

8.1 Water Quantity Monitoring

At Patuxent Research Refuge most water quantity monitoring is carried out by the USGS (Table 9 and Figure 7). Other water quantity monitoring may be taking place in the area but was not identified in our review of available data.

Table 9: Water quantity monitoring sites near Patuxent Research Refuge organized by agency.

Figure 7 ID	Site ID	Type	Agency
96	Patuxent River at Laurel, MD 1592500	streamflow	USGS
97	Patuxent River at Bowie, MD 1594440	streamflow	USGS
113	Little Patuxent River at Savage, MD 1594000	streamflow	USGS
98	Well 390303076463201-AA Cb 1	groundwater	USGS
99	Well 390419076432301 – AA Cc 124	groundwater	USGS
100	Well 390423076432001 – AA Cc 40	groundwater	USGS
101	Well 390437076432302 – AA Cc 119	groundwater	USGS
102	Well 390456076432501 – AA Cc 121	groundwater	USGS
114	18511 – Laurel 3W, MD	climate	USHCN

Patuxent Research Refuge staff provided locations of an additional 31 groundwater monitoring wells that are not included in Table 9, above. These wells are mapped in Figure 7 but are not being actively monitored like the sites listed in Table 9.

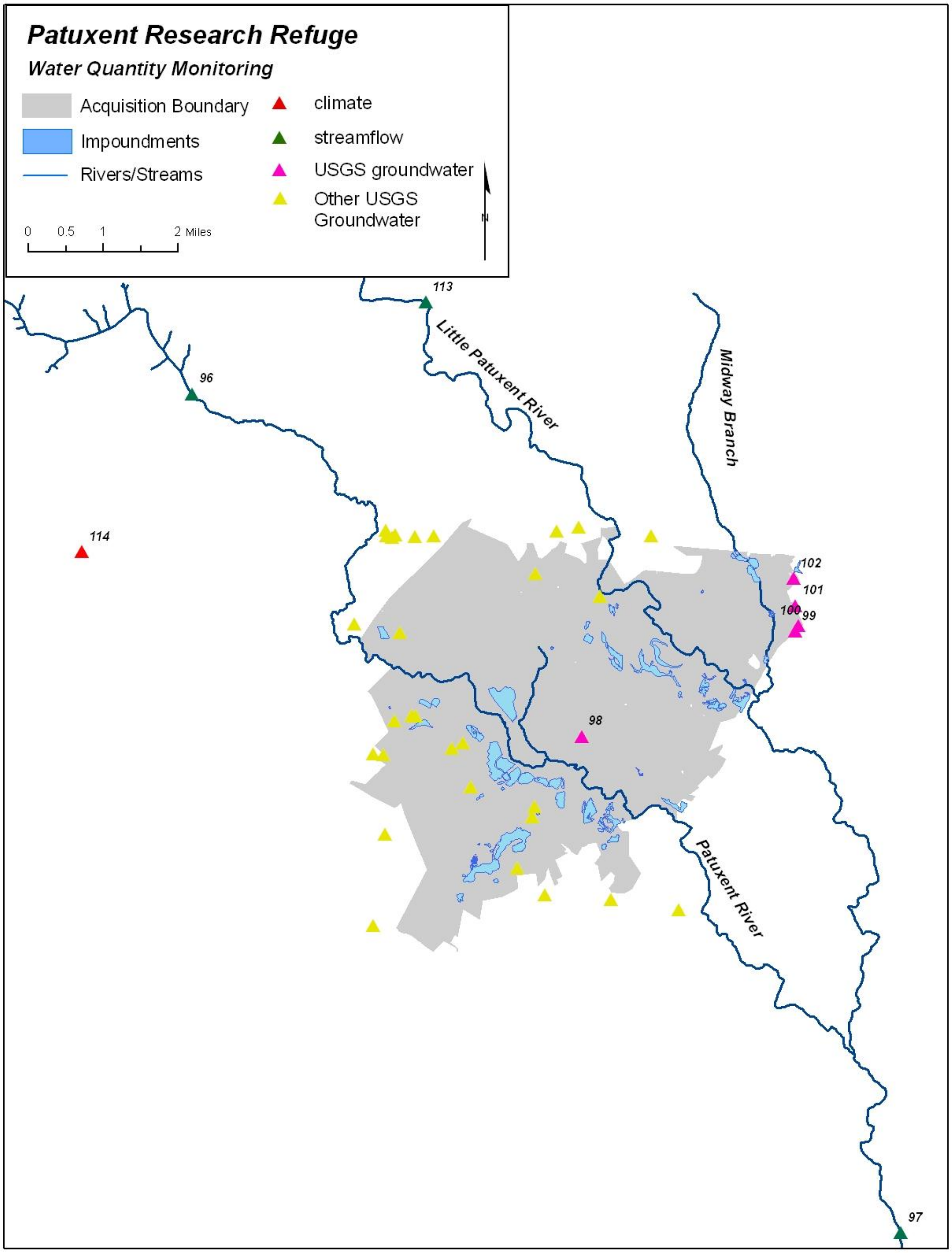

Figure 7: Location of water quantity monitoring sites near Patuxent Research Refuge, Laurel, MD. Additional information on these sites is listed in Table 9.

8.2 Water Quality Monitoring

There are many groups who have collected or are currently collecting water quality data in the vicinity of Patuxent Research Refuge. In 2010, Mary Kazantseva collected available water quality data from various entities that have worked in the vicinity of Patuxent Research Refuge (Table 10 and Figure 8). Other water quality monitoring may be taking place in the area but was not identified in her review.

Table 10: Water quality monitoring type and selected sites on and near the refuge, organized by agency responsible for the collections. Data provided by Mary Kazantseva.

Agency	Type of Monitoring	Number of Sites
Anne Arundel County	Stream Morphology / Invertebrates	16
U.S. Army: Fort George Meade	Basic Water Chemistry / Invertebrates	15
Fort George Meade	Groundwater Chemistry / Contaminants	41
Maryland Department of Natural Resources	Basic Water Chemistry / Invertebrates	23
Prince Georges County	Basic Water Chemistry / Invertebrates	6
Patuxent Riverkeepers	Basic Water Chemistry	3
USGS	Water Chemistry	3
Washington Suburban Sanitation	Nutrients	1
Total		***108***

Mary Kazantseva's work identified numerous water quality monitoring efforts around the refuge. However, most of the monitoring is taking place outside of the refuge boundary. Additionally, there appears to be limited coordination between the various entities collecting these data. Most of the monitoring points presented in Figure 8 represent one-time sample collections between 1999 and 2010 to support a particular study or inventory. Regular data collection is carried out by the USGS, FGGM, and Washington Suburban Sanitation Commission. The USGS has collected multiple water samples at their stream gages on the Patuxent and Little Patuxent rivers. FGGM samples groundwater from wells in the north tract of the refuge. The Patuxent Riverkeepers work with volunteers to collect basic water chemistry information where the Patuxent and Little Patuxent exit the refuge. The Maryland Biological Stream Survey (MBSS) has sites on the refuge where aquatic species are inventoried periodically. Anne Arundel and Prince George's County have collected data on the refuge as part of larger monitoring efforts. Washington Suburban Sanitation Commission collects water quality data at the discharge of its wastewater treatment plant in Laurel.

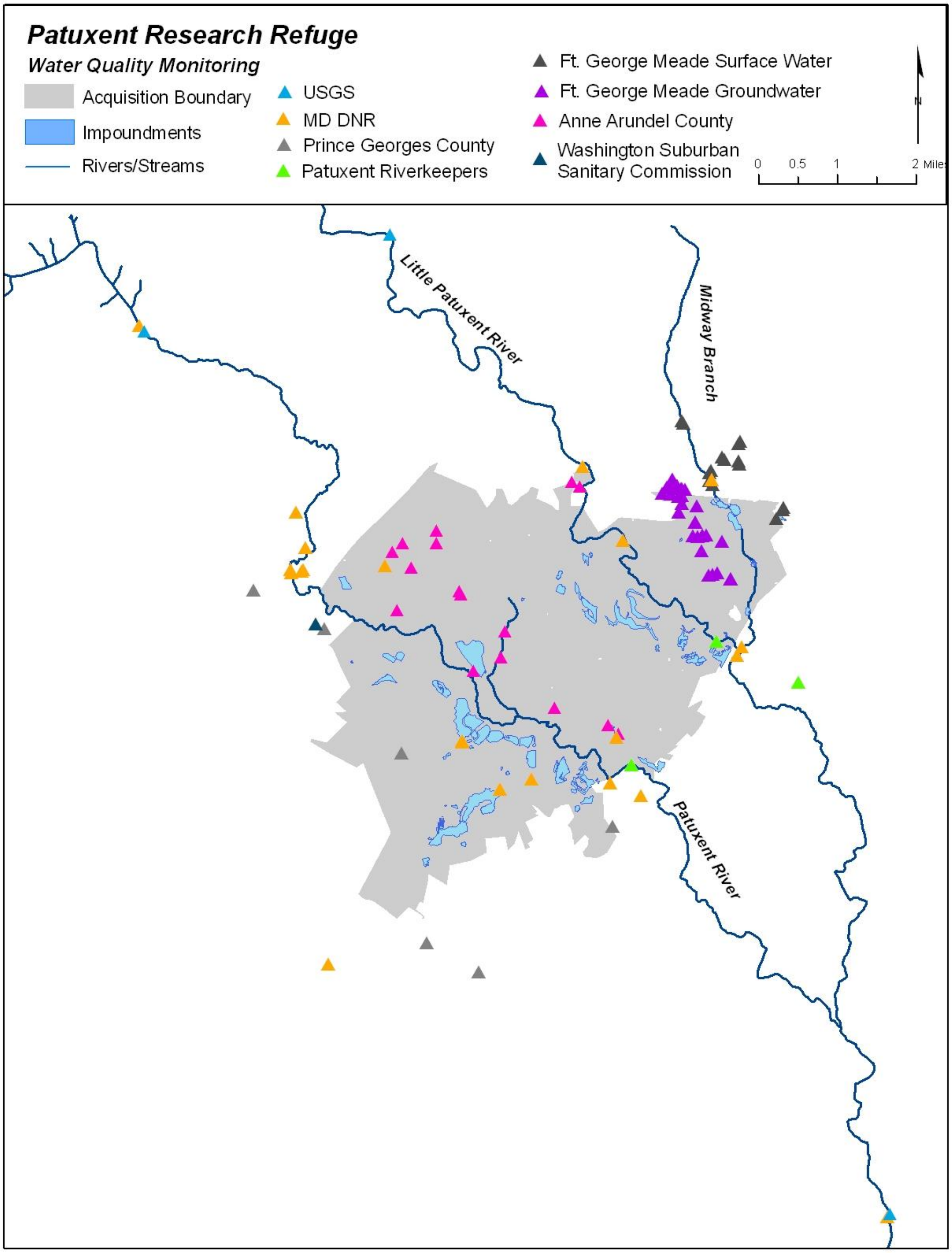

Figure 8: Location of water quality monitoring sites near Patuxent Research Refuge, Laurel, MD. Sites are colored by agency responsible for data collection. Many sites represent one-time sample collections.

9. LONG-TERM CLIMATE PATTERNS

A variety of datasets exist that can be used to evaluate long-term climate trends at refuges in Region 5. Some of these data are included in the WRIA to provide a preliminary analysis of trends in precipitation, temperature, and stream runoff. Data were analyzed for trends using the nonparametric Mann-Kendall statistical test. This test can be used to determine if there is a linear trend in a dataset and whether or not that trend is statistically significant ($\alpha < 0.05$) (Helsel and Hirsch 2002).

9.1 U.S. Historical Climatology Network (USHCN)

The USHCN is a network of climate monitoring sites maintained by the National Weather Service. Sites in the network are selected because their location and data quality make them well suited for evaluating long-term trends in regional climate. The closest site to Patuxent Research Refuge is located in Laurel, MD. Data from the site illustrates trends in precipitation and air temperature in northeast Maryland from 1940 to the present (Figures 9 – 11).

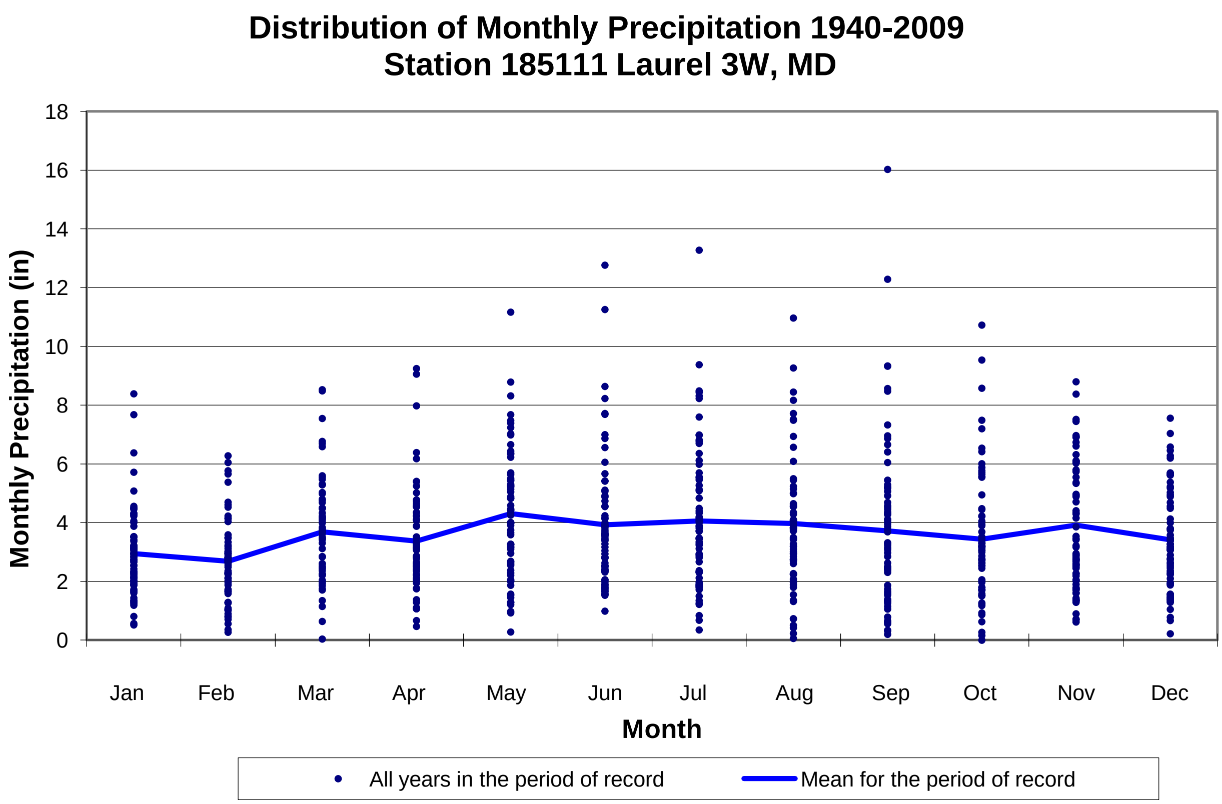

Figure 9: Distribution of total monthly precipitation at USHCN site 185111 in Laurel, MD: 1940 – 2009.

Trends presented in Figure 9:

- Relatively uniform precipitation distribution across the year. Summer months (May-September) appear slightly wetter than other months of the year.
- Average monthly precipitation in Laurel, MD is 3.62 inches
- Average annual precipitation total for the year is 43.2 inches

Precipitation patterns were evaluated by calculating the difference between each year's average precipitation and the average for all years. Presented as a percent, this approach can be used to identify years of above average, or below average, precipitation (Figure 10).

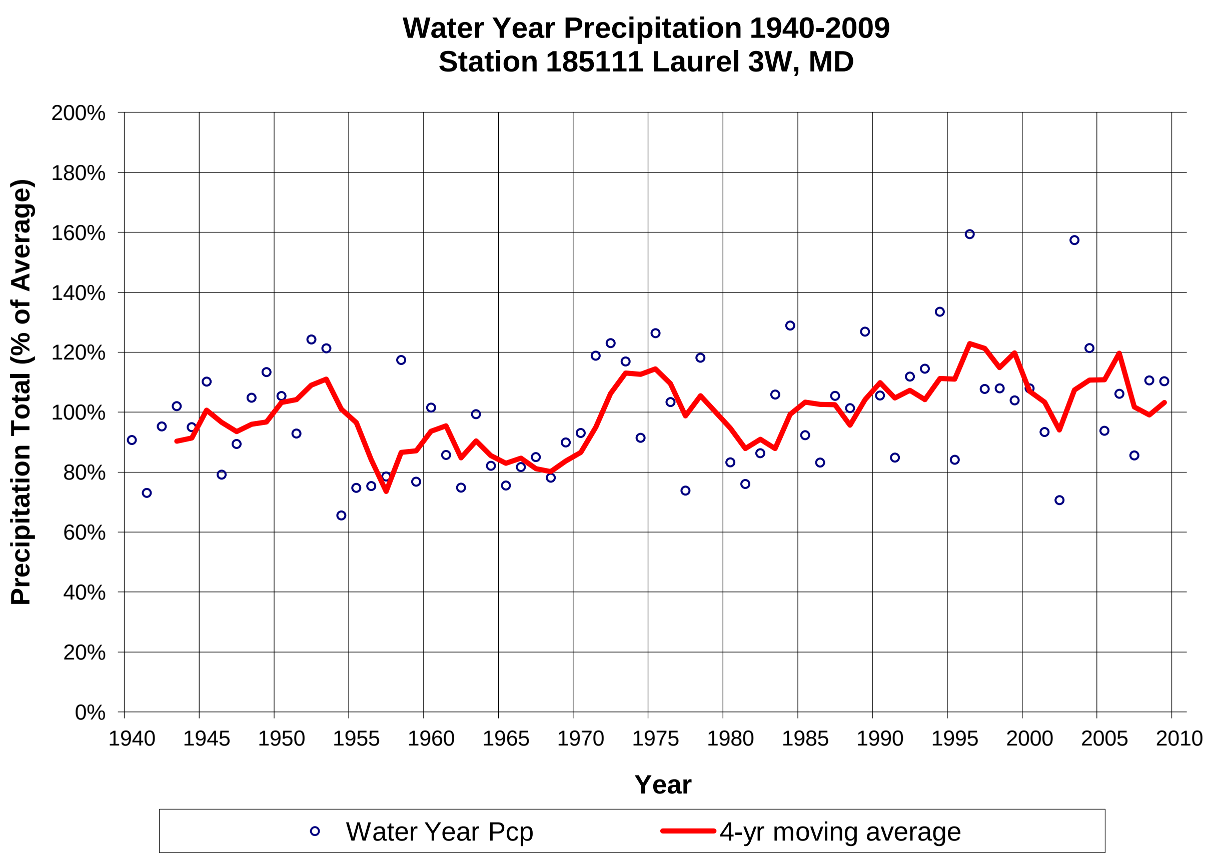

Figure 10: Percent of total Water Year precipitation at the Laurel, MD USHCN site between 1940 and 2009. The Water Year is from 10/1 – 9/30 of each year.

Trends presented in Figure 10:

- Data in Figure 10 suggest the period between 1955 and 1970 was an extended period of below average precipitation.
- Other "dry periods" include the early 1940s and early 1980s.
- Early 1950s, mid-1970s, and 1990s appear to be periods of above average precipitation.
- Water year precipitation totals have increased approximately 0.11 inches/year over the period of record (1940 – 2009). The increasing trend is statistically significant using the nonparametric Mann-Kendall test.

Monthly temperatures at the Laurel, MD USHCN site were also reviewed to identify any patterns in air temperature since 1940 (Figure 11).

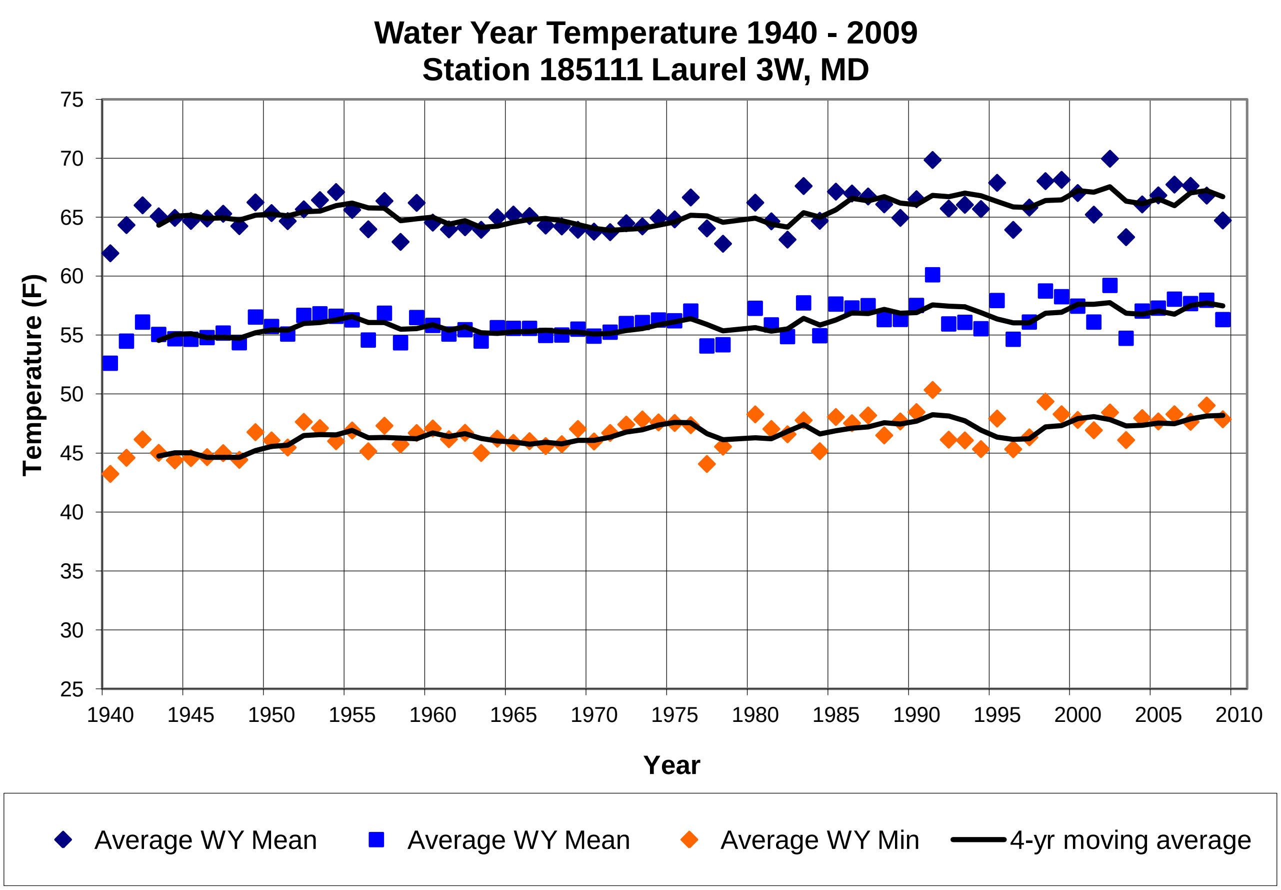

Figure 11: Average temperatures for the Water Year: 1940 – 2009 at the USHCN station in Laurel, MD. The Water Year extends from 10/1 – 9/30 of a year.

Trends presented in Figure 11:

- Average water year maximum temperatures have increased approximately 0.03 °F / year during the period of record (statistically significant trend).

- Average water year mean temperatures have increased approximately 0.04 °F / year during the period of record (statistically significant trend).

- Average water year minimum temperatures have increased approximately 0.04 °F / year during the period of record (statistically significant trend).

Maximum, mean, and minimum water year temperatures measured at the Laurel, MD USHCN station have all increased significantly since 1940. These increases agree with studies showing global temperatures are rising (Bates et al. 2008) and regional studies showing increasing air temperatures in the mid-Atlantic region of the United States (Polsky et al. 2000).

9.2 USGS Hydro-Climatic Data Network (HCDN)

The HCDN is a network of USGS stream gaging stations that are considered well suited for evaluating trends in stream flow conditions. Sites in the network have periods of record that exceed 20 years and are located in watersheds that are relatively undisturbed by surface water diversions, urban development, or dams.

The closest HCDN stream flow gage near Patuxent Research Refuge is located on the Patuxent River near Unity, MD. The station's record begins in 1944. Because the station is located upstream of Washington D.C.'s water supply reservoirs, the record is unaffected by water management activities in the basin (Figures 12 and 13). Runoff patterns at the stream gage in Unity are thought to reflect typical runoff patterns in creeks and streams at Patuxent Research Refuge.

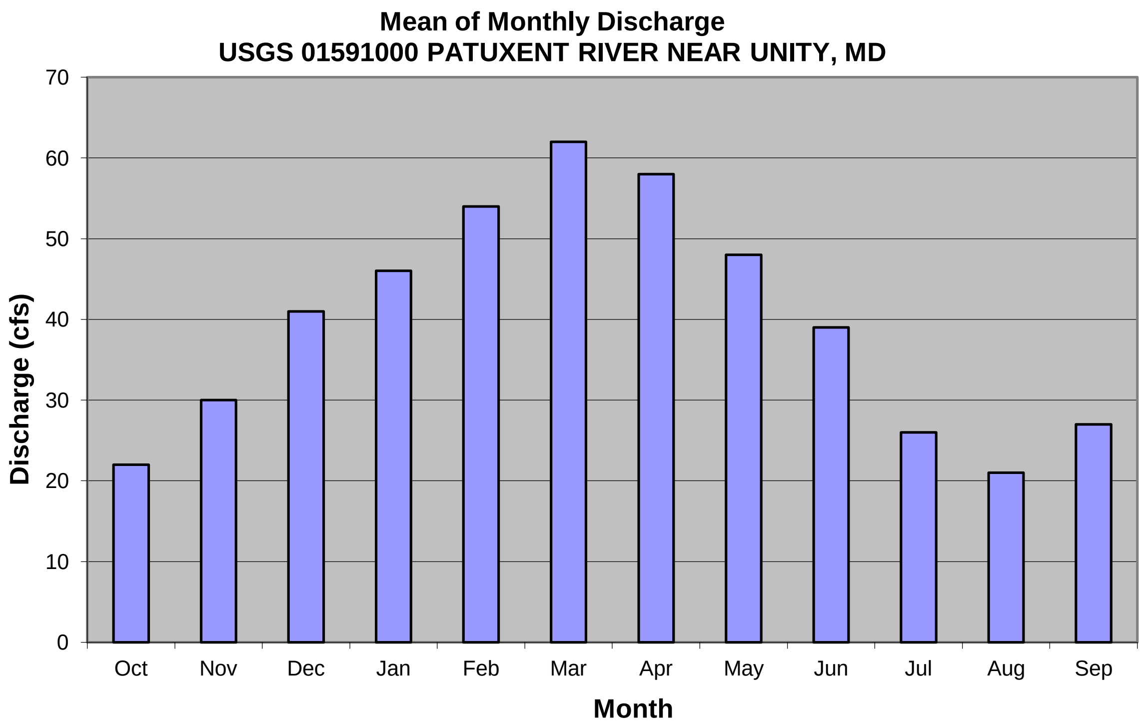

Figure 12: Average monthly discharge on the Patuxent River near Unity, MD 1945-2009

Trends presented in Figure 12:

- Highest flows occur during the late winter and early spring. Typically peaking in March of each year.
- Lowest flow conditions of the year occur in the summer months.
- Slight increases in September flows may be related to the occasional tropical weather system that brings considerable rainfall to the mid-Atlantic.
- Average mean monthly discharge for the year is approximately 39 cfs.

Flow patterns were evaluated by calculating the difference between each year's average discharge and the average for all years. Presented as a percent, this approach can be used to identify years of above average, or below average, runoff (Figure 13).

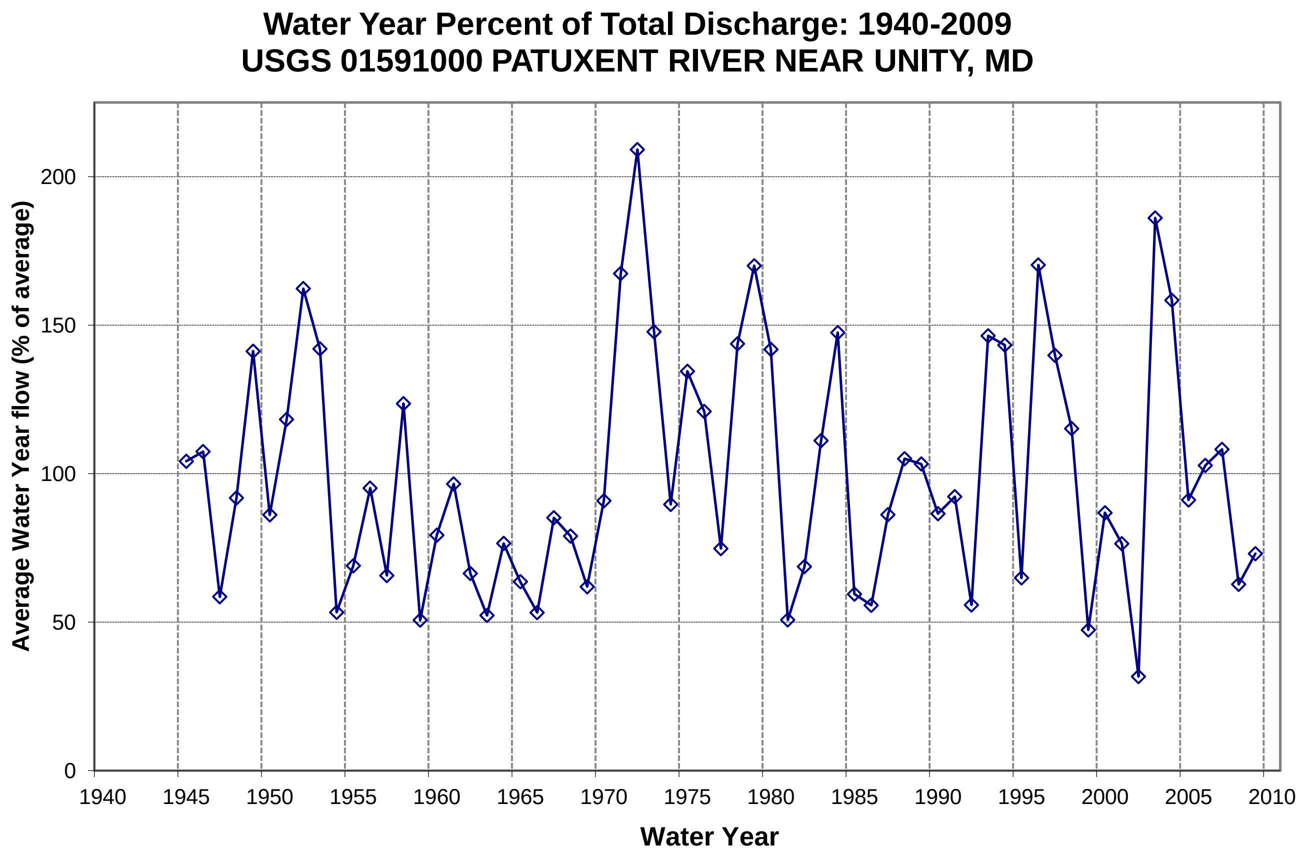

Figure 13: Percent of the average water year flow on the Patuxent River at Unity, MD: 1940-2009. Average water year flow from the period of record is 39 cubic feet per second (cfs).

Trends presented in Figure 13:

- Dry period between 1955 and 1970 is a particularly long period of below average flows at this site. This corresponds with below average precipitation patterns during the same period (Figure 10).
- The highest average flow for the water year was in 1972 (82 cubic feet per second (cfs)).
- The lowest average flow for the water year was in 2002 (12 cfs).

Streamflow in the Patuxent at Unity roughly corresponds with total precipitation by water year data presented in Figure 10. Unlike precipitation data, water year average discharge has not increased or decreased significantly over the period of record (1945 – 2009).

9.3 Future Climate Predictions

The Intergovernmental Panel on Climate Change (IGPCC) predicts the U.S. Northeast will experience earlier spring snowmelt and reduced summer runoff as the global climate warms in response to human emissions of greenhouse gasses (Bates et al. 2008, Mack 2008). Hayhoe et al (2007) review historic climate data and climate change models to evaluate the Northeast's response to global climate change. Results of the Hayhoe's analyses are summarized below:

1. Air temperature records in the US Northeast show consistent signs of warming since the 1970s.

2. In the last 40 years winter snowpack has been decreasing, the onset of peak streamflow has occurred earlier in the year, the duration of ice cover on lakes has decreased, and the length of the growing season has increased.

3. Under current greenhouse gas emission scenarios winter precipitation is predicted to increase 10-15% and summer precipitation is predicted to not change or decrease.

4. All model scenarios show increases in temperature and further exacerbation of the trends observed since the 1970s.

10. WATER RIGHTS

The laws governing water use in Maryland are outlined in Title 26, subtitle 17, Chapter 6 of Annotated Code of Maryland. Individuals, corporations, municipalities, and federal agencies are considered "persons" that can apply to use waters of the state. The Maryland Department of the Environment (MDE) manages and administers water use by issuing permits to appropriate surface water and groundwater. Two of the key concepts of Maryland water law are the idea of reasonable use and riparian rights.

Whether or not a use is reasonable is determined by MDE when reviewing new applications. Water use is allowed so long as there is no ". . . unreasonable interference with other persons also attempting to make reasonable use of water." Based on conversations with MDE staff, it appears that determinations of "reasonable" and "unreasonable" are evaluated on a case by case basis.

Applicants cannot use water of the state unless they own property adjacent to the water source. For surface water, the applicant must own land bordering the target river, lake, or stream.

Additional details of Maryland's water use regulations are outlined below:

1. Water use in excess of 10,000 gallons/day from surface water or groundwater sources requires a permit from MDE.

2. Permits are obtained from Maryland Department of Environment: Office of Water Supply

3. Permits are issued for 12 years and are reviewed by MDE when they come up for renewal.

4. Permittees are required to report water use to MDE every 6 months. Agricultural water users are required to report once per year.

5. MDE posts new applications, organized by county, at the Office of Water Supply website. Notices are also placed in local newspapers. Additionally MDE notifies neighboring landowners and local county officials in writing.

6. MDE reviews the potential impacts of all new applications internally. If there is a conflict over a new permit application, MDE may hold a public hearing to address the issues.

7. Maryland Department of Natural Resources sets minimum streamflow criteria for streams in the state. New water use applications will not be approved if MDE believes they will cause a river to drop below the minimum streamflows.

8. Maryland Geological Survey identifies the water surface elevation of the state's aquifers at pre-pumping and 80% of pre-pumping levels. Groundwater applications are evaluated to ensure the new pumping will not lower the aquifer's surface below the 80% level.

9. MDE does not consider wetland impoundments uses under state water law. However, the diversion of water from a water body to fill impoundments is regulated under Maryland's water code.

Patuxent Research Refuge holds four water use permits with MDE to use groundwater from the refuge's water supply wells:

- Permit PG1958G203(02) allows for water use from the Patapsco Aquifer for potable supply and sanitary facilities using wells 3, 4, 9, 10, and 12.

- Permit PG1958G103(03) allows for water use from the Patapsco Aquifer for potable supply, sanitary facilities, and wildlife watering using wells 1, 2, 5, 6, and 13.

- Permit PG1958G003 (05) allows for water use from the Patuxent Aquifer for wildlife watering using wells 7 and 14.

- Permit AA00G006 (01) allows for water use from the Patapsco Aquifer for potable and sanitary facilities at the visitor contact station using well 16.

Flow meters installed on the wells' supply lines are read regularly by the refuge's maintenance staff. These data are summarized in bi-annual water use reports and submitted to MDE.

11. PERCEIVED THREATS

This section discusses some of the challenges the refuge's water resources face. For the purposes of this initial review the primary water resources of interest are the Patuxent and Little Patuxent Rivers, tributary channels, forested wetland habitat adjacent to the rivers, and the water-table aquifer that contribute to the rivers and wetlands on the refuge.

11.1 Stormwater Runoff

The Patuxent Research Refuge is an island of mostly forested land surrounded by suburban development. Stormwater runoff from urban development in the watersheds of the Patuxent and Little Patuxent rivers contributes to their degraded water quality (MDE 2011). Although smaller wetlands and tributary channels inside the refuge boundary may not be affected by development outside the refuge, the refuge's boundary does not guarantee protection. In the late 1980s sediment runoff from an adjacent landfill reached tributary channels and wetlands on the refuge (Pinkney 2000). The poor water quality conditions documented by Victoria and Markusic

(2009) also suggest neighboring land use and the associated stormwater runoff has a negative influence on refuge water resources.

11.2 Refuge Roads

The refuge contains many miles of small channels, tributary to the Patuxent and Little Patuxent Rivers. There are many roads crossing these channels, most of which were built prior to establishment of the refuge. Using the available GIS layers there are about 50% more road miles than tributary stream channel miles on the refuge (Table 11).

Table 11: Approximate miles of refuge roads and tributary channels in the Patuxent Research Refuge. Road miles calculated from refuge roads GIS shapefile. Channel miles calculated from NHD 1:24,000 scale GIS data layer.

Miles	Description
73	Miles of channels tributary to Patuxent, Little Patuxent, Thomas Branch, and Midway Branch on or within 0.1 miles of Patuxent Research Refuge. From USGS NHD 1:24K
99	Miles of refuge roads at Patuxent Research Refuge. From refuge road GIS data layer.

Roads can degrade aquatic habitat by increasing sedimentation, fragmenting habitat, and providing pathways for invasive species (Gucinski et al. 2000). An additional problem in the vicinity of Patuxent Research Refuge is the migration of road salt residue into aquatic habitats (MDE 2011). The extent of the road network ensures that most of the refuge habitat is in close proximity to some type of road. To assess the spatial coverage of the road network, we identified "roadless" areas at Patuxent Research Refuge. These are defined as areas more than 0.1 mile of refuge roads and 0.25 miles of a major highway or interstate (Figure 14). Of the 12,841 acres of habitat in the refuge's acquisition boundary, approximately 36% could be considered "roadless". The largest of these parcels are along the floodplain of the Little Patuxent River and its major tributary, the Midway Branch. Other large parcels are found where the Patuxent River enters the refuge and in the vicinity of Shaefer Lake.

It seems likely that refuge roads compromise the aquatic habitat of the small streams and creeks on the refuge. Victoria and Markusic (2009) found that many of the refuge's creeks in the North Tract show signs of excessive sedimentation and depressed biological communities. Although they did not attribute these problems to refuge roads they recommended more detailed evaluations of conditions in refuge streams to identify the probable causes of impairment.

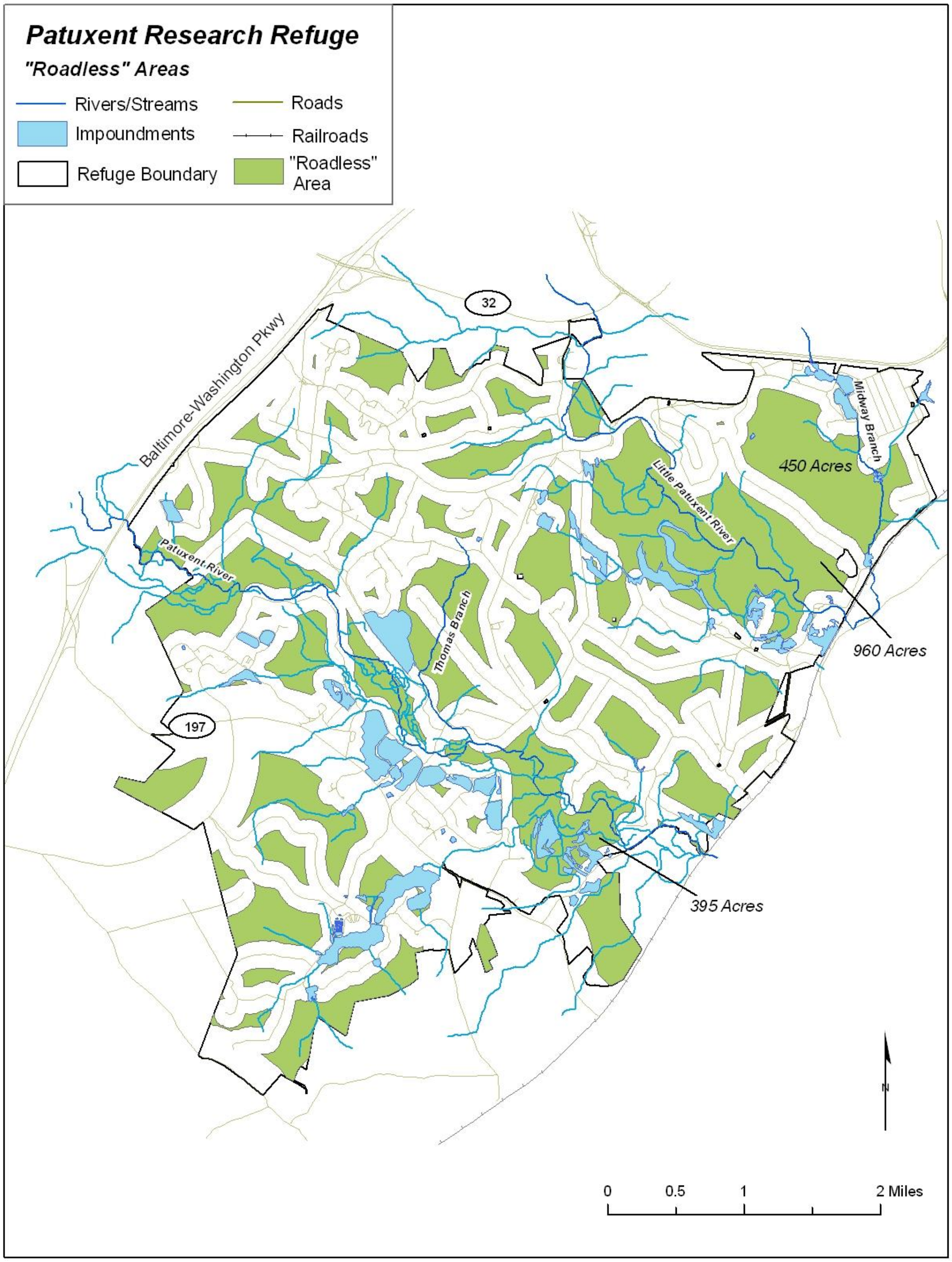

Figure 14: Areas of Patuxent Research Refuge that are more than 0.1 mile from a refuge road and more than 0.25 miles from a Major Road. Acreages are identified for the three largest "roadless" polygons.

11.3 Upstream Water Diversions

Dams fundamentally change flow and sediment transport conditions in the rivers they control (Collier et al. 1996). The Patuxent River's flow on the refuge is controlled by releases from Rocky Gorge Reservoir. Records from the [USGS stream gage](#) on the Patuxent near Laurel, MD show changes in streamflow following construction of the dam in March 1954 (Figure 15).

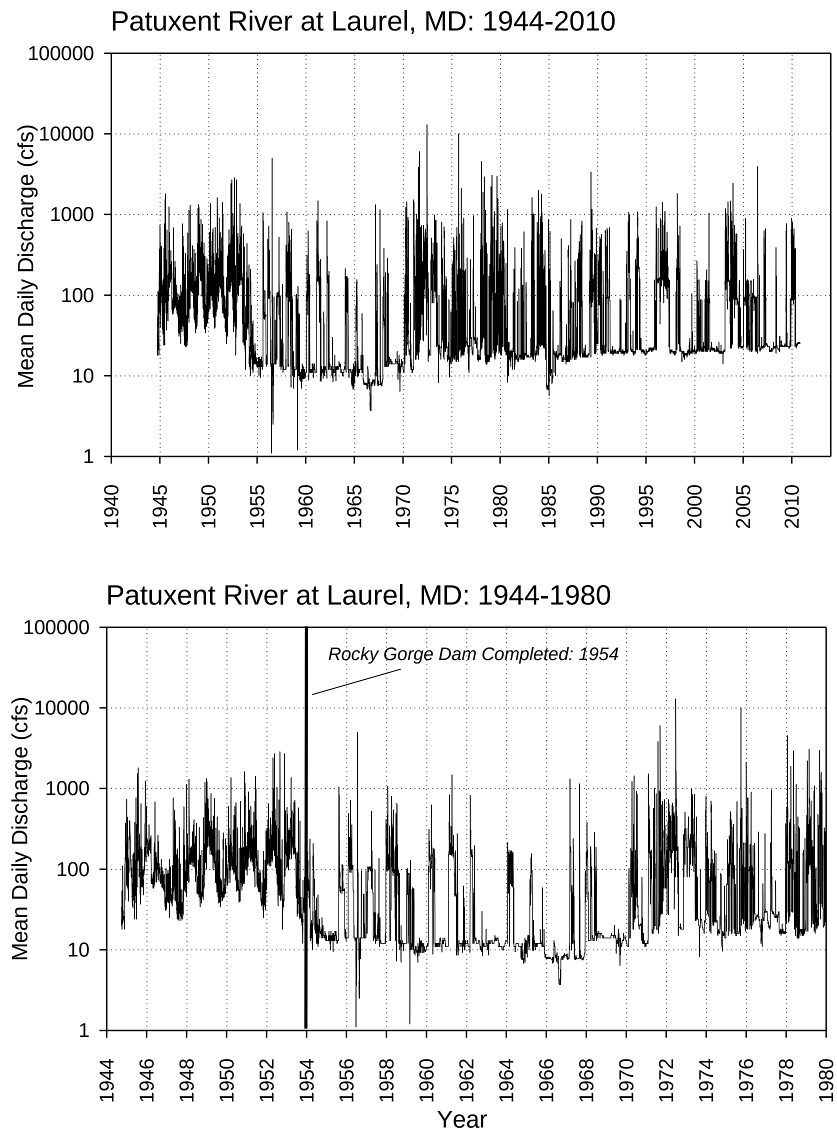

Figure 15: Mean daily discharge in the Patuxent River near Laurel, MD. Data from USGS stream gage 01592500.

Flow in the Patuxent decreased following construction of Rocky Gorge Dam. The decline was particularly pronounced between 1955 and 1970 during an extended drought period in the Mid-

Atlantic. Although releases appear to have increased since 1970, minimum streamflow in the Patuxent still appears lower than it was prior to dam construction. Reduced minimum streamflows and reduced sediment transport has undoubtedly affected the geomorphology of the river downstream. Further analysis is necessary to evaluate these impacts in more detail

11.4 Groundwater Development

Anne Arundel and Prince George's County anticipate increasing pumping from the Patuxent and Pataspco aquifers (see Figure 4) to meet public water supply needs. Future groundwater development in the Coastal Plain Aquifer System could lower water levels in the Water-table aquifer under the Patuxent Research Refuge (Andreasen 2007). This could lead to reduced streamflows in the refuge's rivers and lower water levels in its wetlands. The impacts of this decline will occur at a regional scale or may be localized near groundwater pumping centers. The effects on the refuge may be subtle and difficult to identify with certainty. When, or if, the refuge has the opportunity to review future groundwater development plans they should consider the potential impacts of the development on refuge water resources.

11.5 Groundwater Quality

Contamination of the Water-table aquifer from FGGM could affect forested wetlands downgradient of the contaminant plume. Ongoing monitoring by the FGGM is designed to determine the extent and migration pattern of the contaminant plume on the refuge. It appears the most likely area where contaminants would discharge into refuge wetlands is near the confluence of the Little Patuxent River and Midway Branch.

12. RECOMMENDATIONS / FURTHER ACTIONS

The primary threat to water resources at Patuxent Research Refuge is poor water quality. Most water quality concerns are associated with pollution from extensive urban development in the watersheds surrounding the refuge. Additionally, refuge roads and historic land use may further compromise water quality.

1. Mary Kazansteva's work highlights the numerous water quality monitoring efforts that have taken place on, and near, Patuxent Research Refuge. Mary determined that the different efforts remain somewhat uncoordinated making it difficult to draw conclusions about refuge water quality conditions from the various datasets. Recommend putting more time into trying to summarize the results of the various monitoring efforts and identify gaps in the data collection efforts. A more thorough review will help identify how to focus future water quality monitoring to better address refuge concerns.

2. Studies and monitoring data indicate water resources on Patuxent Research Refuge suffer from compromised water quality conditions. This preliminary review suggests causes are related to stormwater runoff from neighboring properties, impacts from refuge roads, and past land use. Recommend implementing a more thorough inventory of water quality conditions in refuge streams and wetlands. This inventory could follow the format outlined in the Victoria and Markusic (2009) report or the Maryland Biological Stream Survey. Such an inventory could help pinpoint impaired waters across the refuge and identify the causes of impairment. Additionally it could identify high quality waters at Patuxent Research Refuge.

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